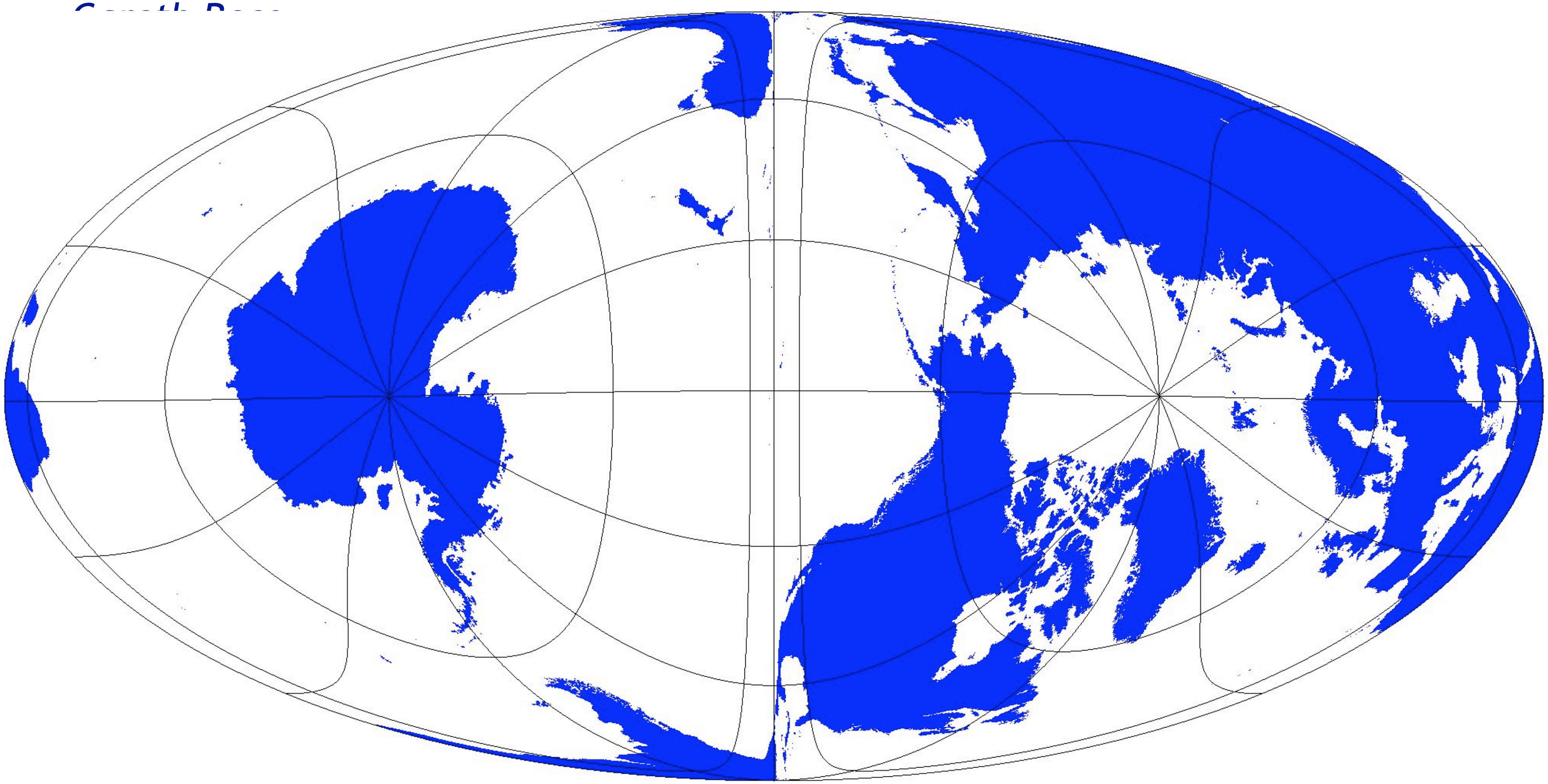
Assessment of ASTER Global Digital Elevation Model data for Arctic research



UNIVERSITY OF CAMBRIDGE

DEMs needed for…

orthorectification

land-use mapping

energy-balance modelling

topographic change detection (e.g. in glacier mass balance studies)

terrain visualisation

infrastructure planning…

Sources of DEMs

national mapping agencies

do-it-yourself (digitisation of topographic maps, field survey, stereophotograpy, InSAR, LiDAR…)

'global' DEMs

- compiled from topographic maps (e.g. GTOPO30, NOAA GLOBE)
- global satellite data (SRTM, GDEM)

Technical issues

coverage

spatial resolution (sampling/posting interval; effective resolution)

height precision and accuracy

artefacts

acquisition date

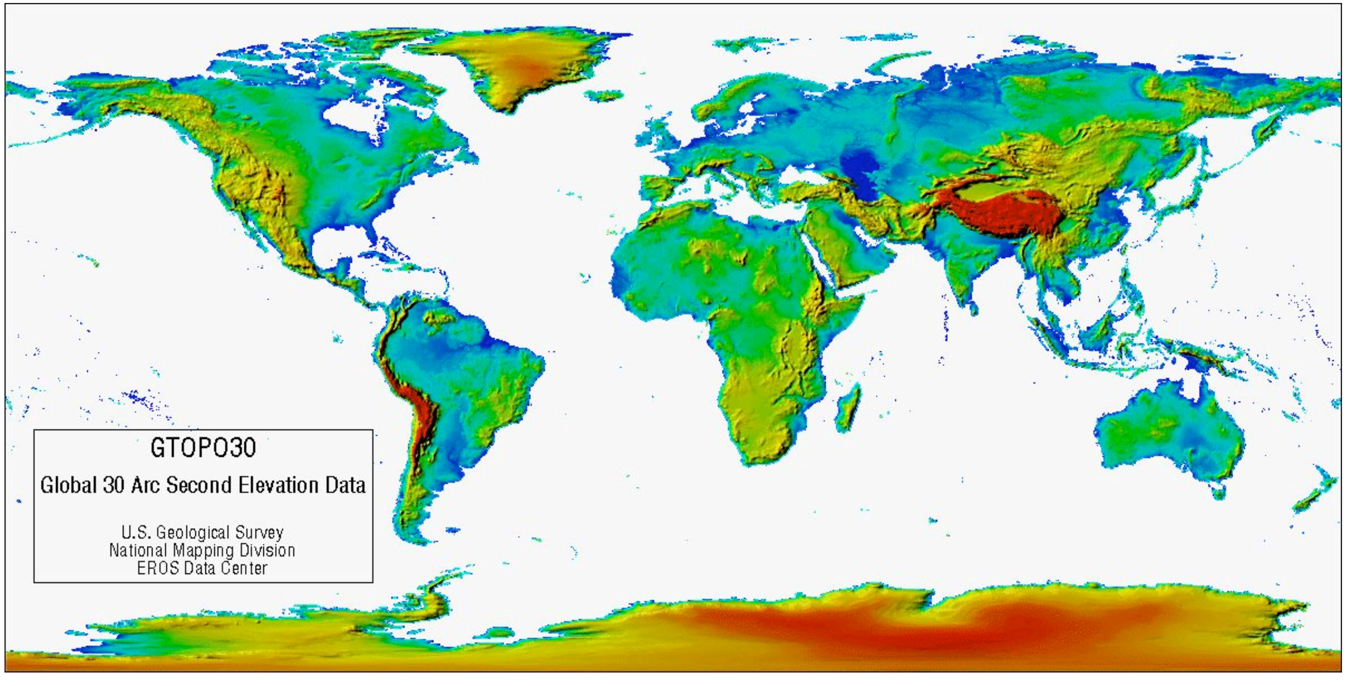
GTOPO30

entire land+ice surface

30 arcsec (≈ 1 km) sample interval

variable height accuracy but typically 20-100m rmse

artefacts from mosaicing and contour digitisation



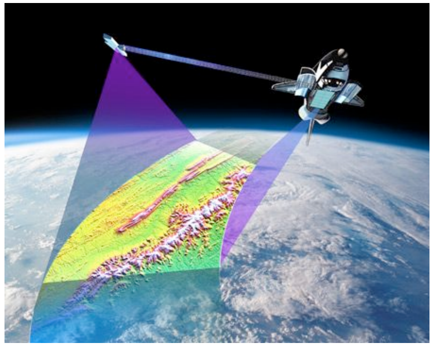
SRTM

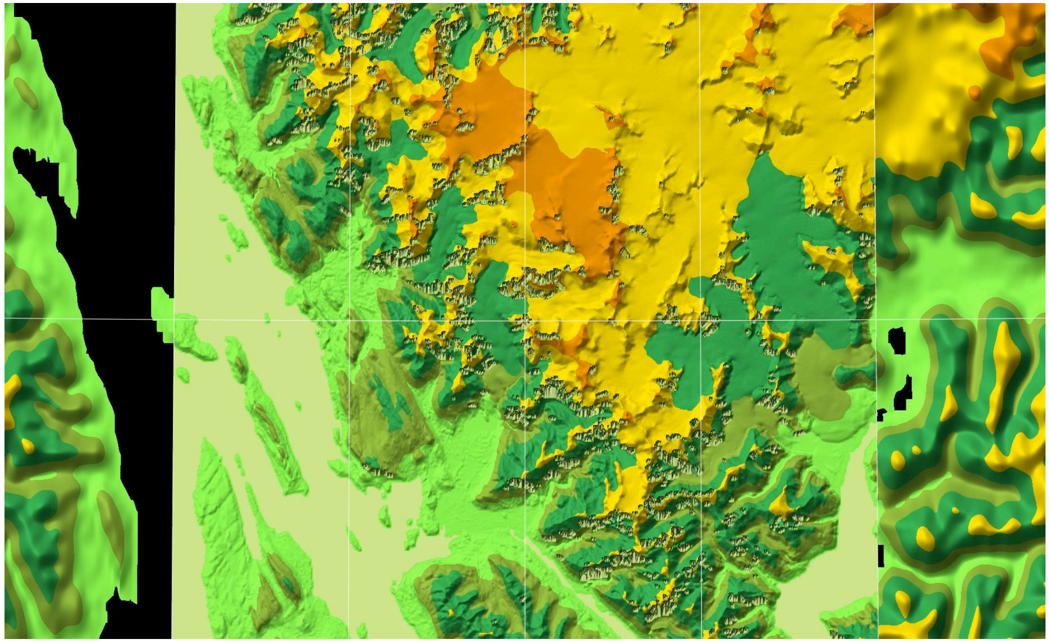
-56° ≤ latitude ≤ +60°

3 arcsec (≈ 90 m) sample interval (1 arcsec in USA)

height accuracy ≈ 10 m

most important artefacts are voids (needs ascending/descending mode *cf* Radarsat)

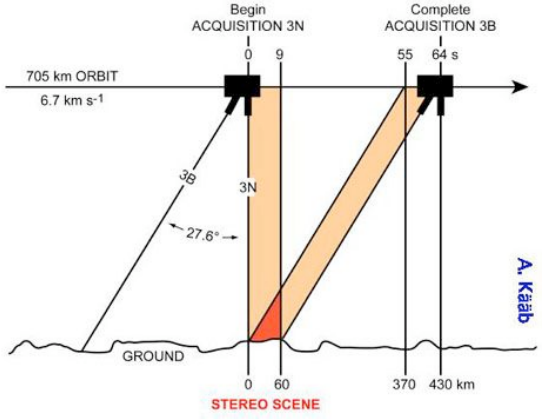




Juneau Icefield

SRTM overlaid on GTOPO30

GDEM (Global Digital Elevation Model)

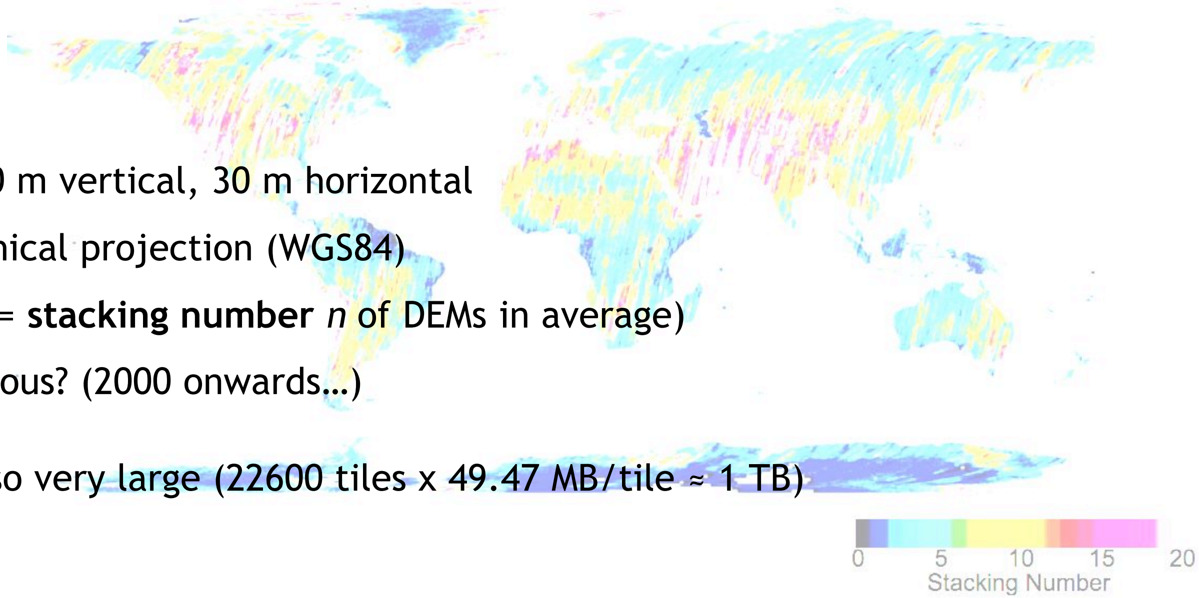


- developed by METI (Japan), NASA (USA)
- released June 2009
- uses automated processing of ASTER stereo imagery
- heights based on average of several DEMs, acquired from 2000
- version 1 is preliminary but freely available

Characteristics

- 1° square tiles @ 1 arcsec resolution (3601 x 3601 samples)
- vertical precision 1 m
- -83 ° ≤ latitude ≤ 83°
- nominal accuracy (95%) 20 m vertical, 30 m horizontal
- GeoTIFF format, Geographical projection (WGS84)
- includes QA data (usually = **stacking number** *n* of DEMs in average)
- acquisition date is ambiguous? (2000 onwards…)

It is an experimental product. It is also very large (22600 tiles x 49.47 MB/tile ≈ 1 TB)

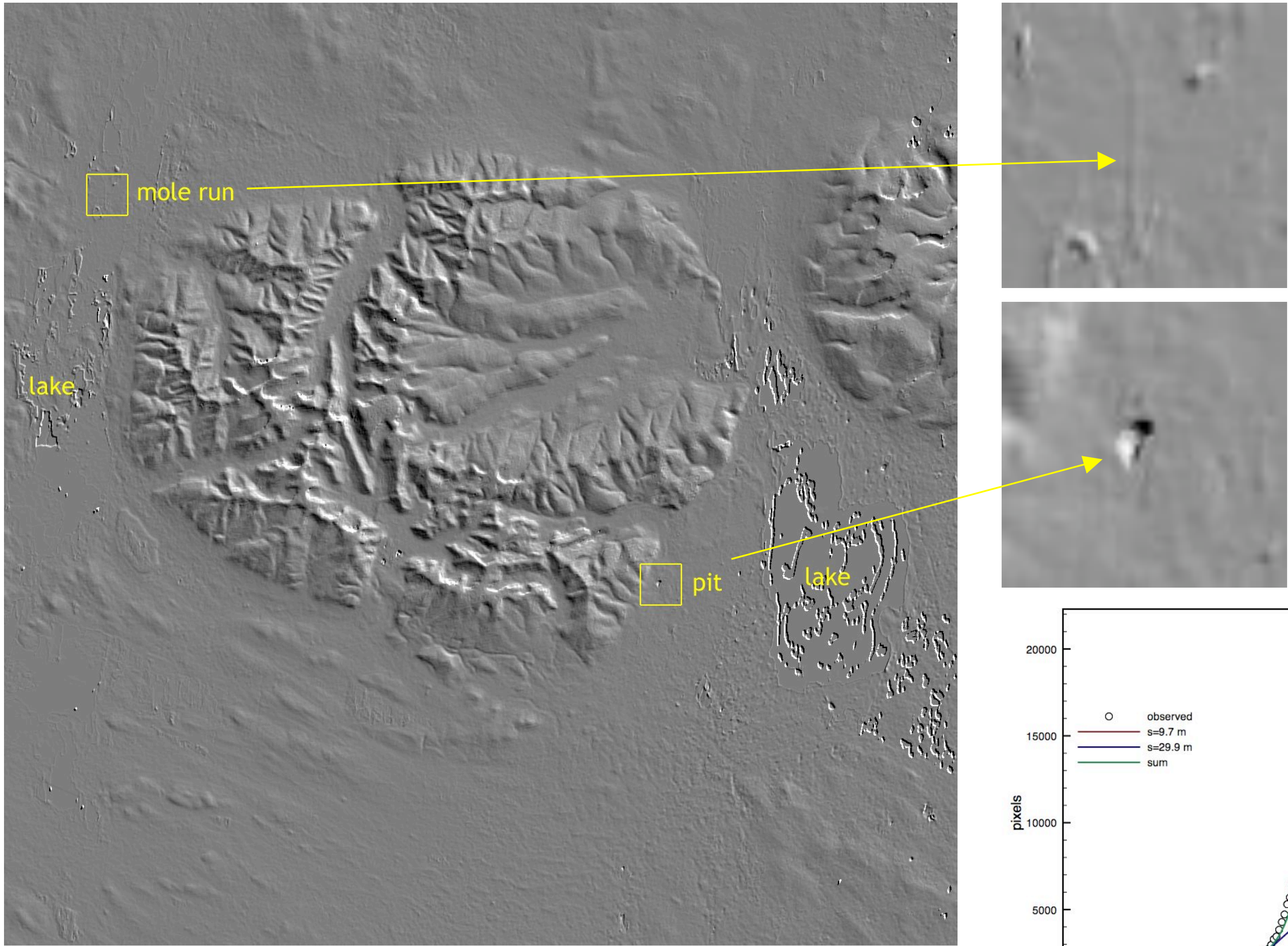


Test sites

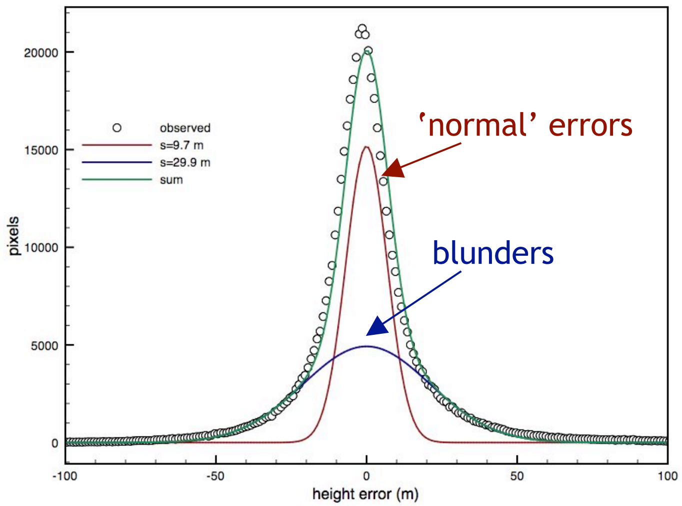
All based on current research interests at SPRI so well-understood sites

Location	Lat	Lon	Dimensions (km)	Terrain	Reference data
Langjökull	64.6	-20.3	56.2 x 58.0	glacier	Airborne LiDAR 10 m
Midre Lovénbreen	78.9	12.0	6.0 x 6.0	glacier, moraine, rock	Airborne LiDAR 2 m
Lakselv	70.1	24.7	12.9 x 10.1	forest, tundra, rock	Airborne LiDAR 2 m
Porsangmoen	69.9	25.2	13.8 x 8.7	forest, tundra, rock	Airborne LiDAR 2 m
Khibiny	67.7	33.7	52.5 x 69.0	forest, tundra, rock	Topomap 50 m

Khibiny mountains, Russia: slope-shaded GDEM



UTM projection zone 36 WGS84 ellipsoid

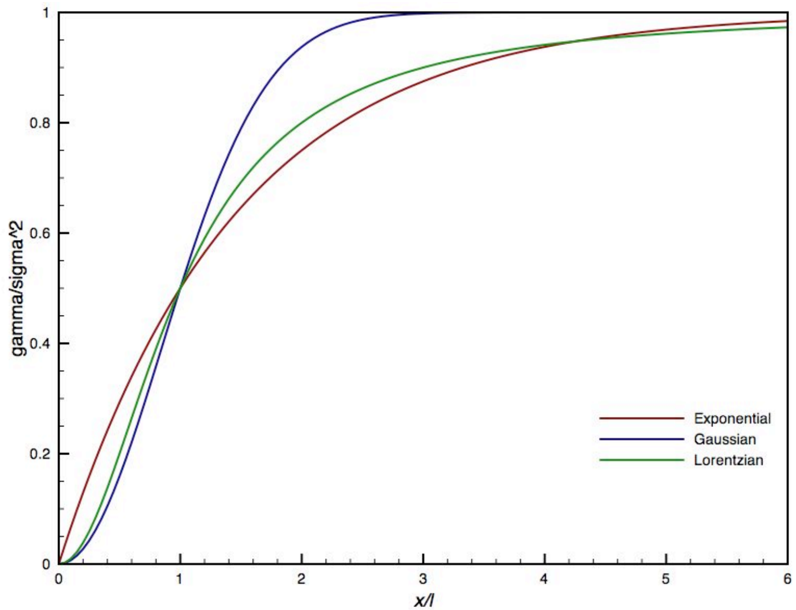


Modelling the spatial distribution of error

$$e(x) = h_{GDEM}(x) - h_{ref}(x)$$ error (<e>=0)

$$\gamma(x) = \frac{1}{2}\left\langle \left[e(x) - e(x'+x) \right]^2 \right\rangle_{x'}$$ semivariance of error…

$$\gamma(x) = \sigma^2 \left(1 - \rho(x)\right)$$ …related to rms error and autocorrelation length of error

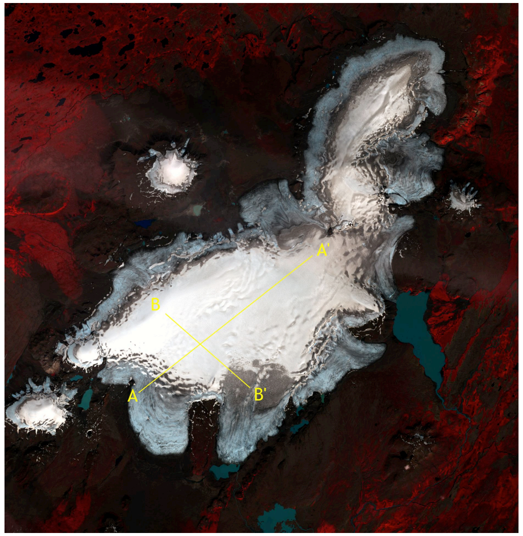


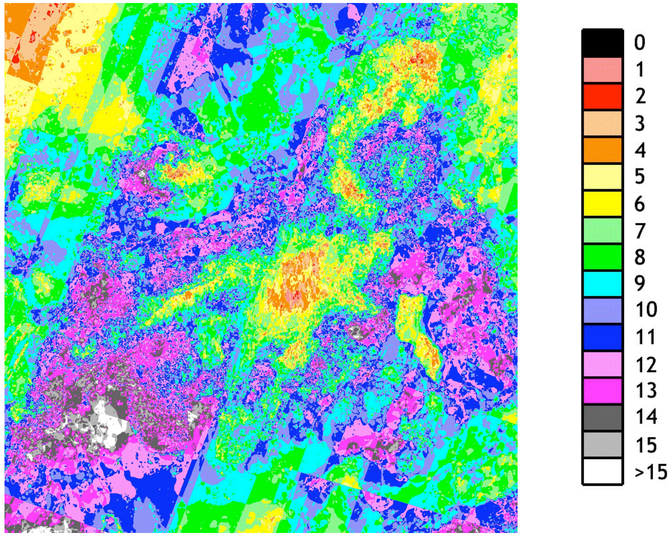
$$\rho(x) = \exp\left(-\ln 2 \frac{x}{l}\right)$$ exponential model

$$\rho(x) = \exp\left(-\ln 2 \left(\frac{x}{l}\right)^2\right)$$ gaussian model

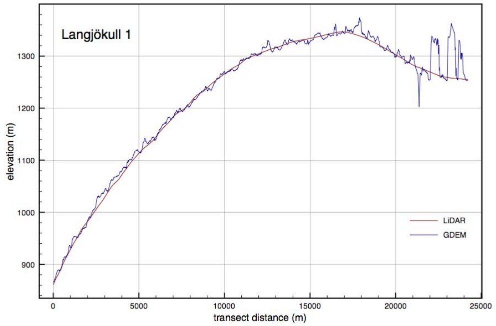
$$\rho(x) = \frac{1}{1 + \left(x/l\right)^2}$$ lorentzian model

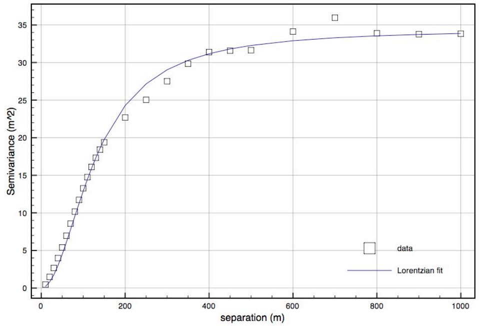
Langjökull



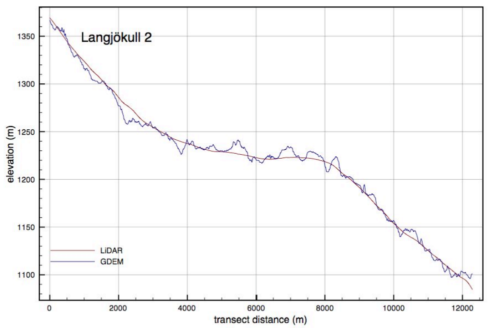


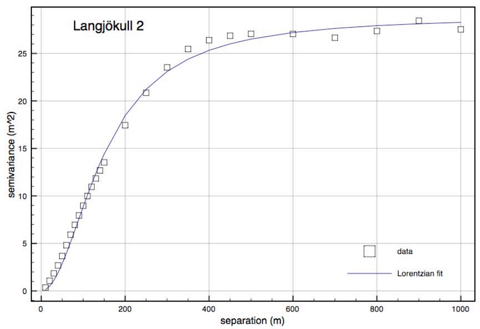
58 km





<*n*>	9.2
σ /m	5.9
l / m	129

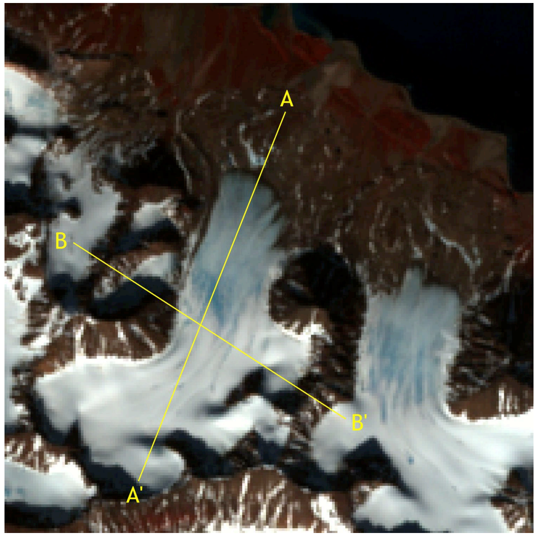


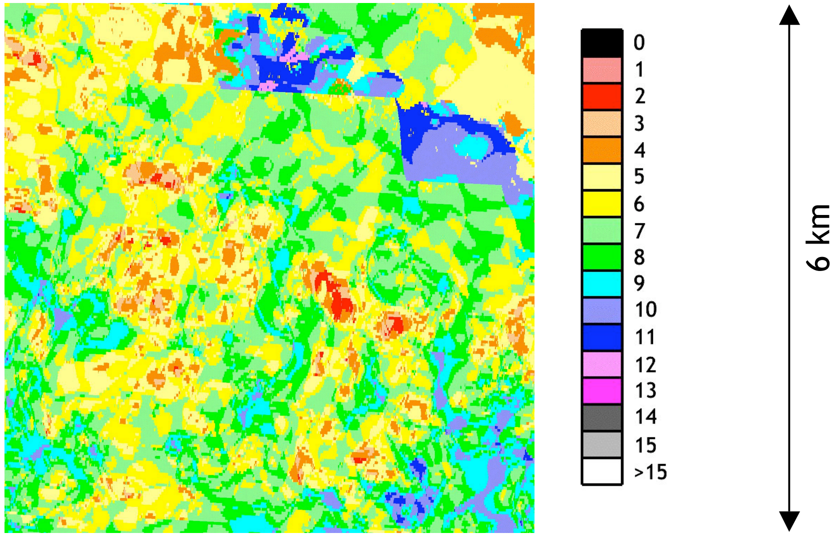


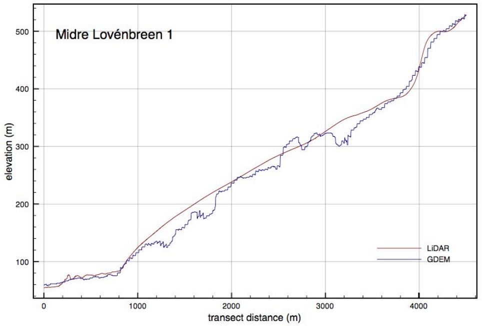
<*n*>	9.5
σ /m	5.4
l / m	150

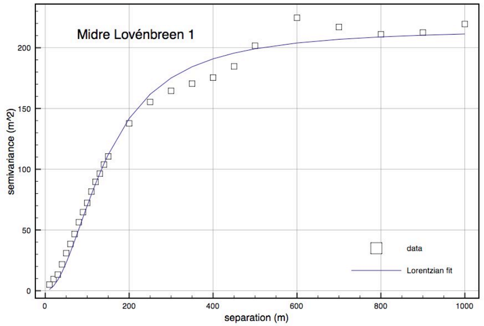
Impressive! Some blunders where n < 5.

Midre Lovénbreen

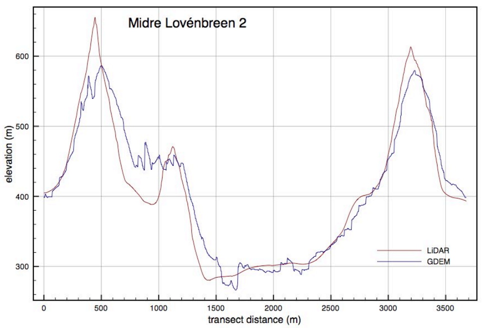


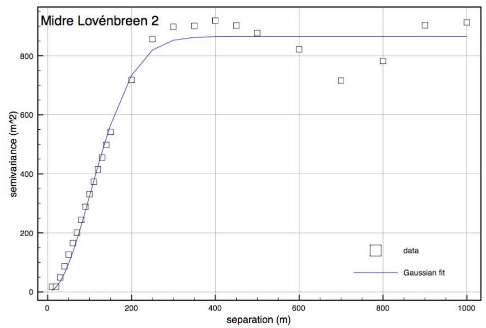






<n>	6.2
σ /m	14.7
l / m	144

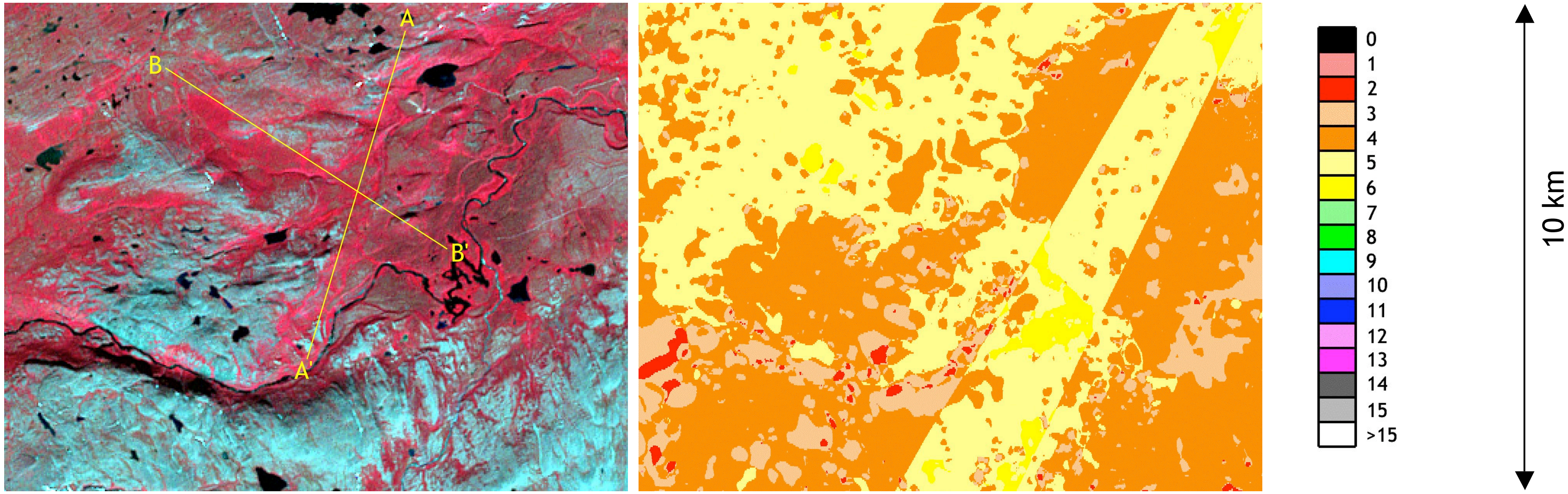


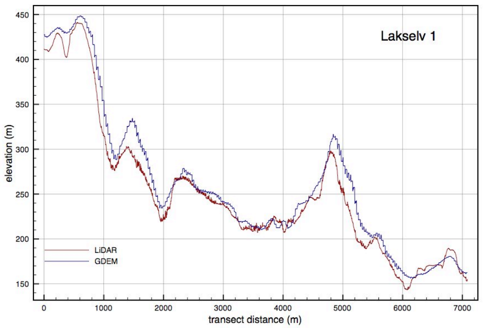


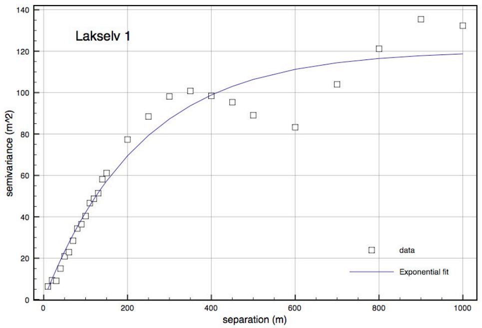
<n>	6.4
σ /m	29.4
l / m	146

Transect A reasonable. Some big errors in B, especially over steep terrain

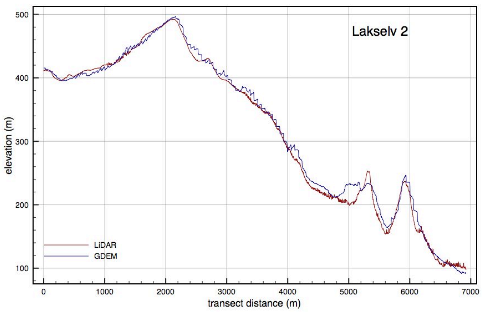
Lakselv

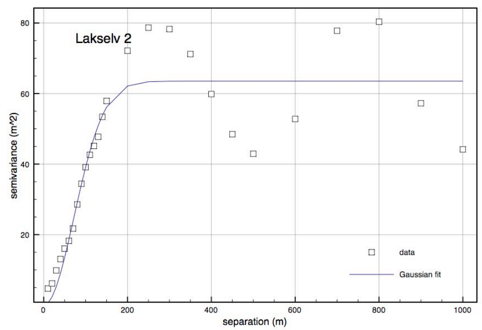






<*n*>	4.6
σ /m	11.0
l / m	232

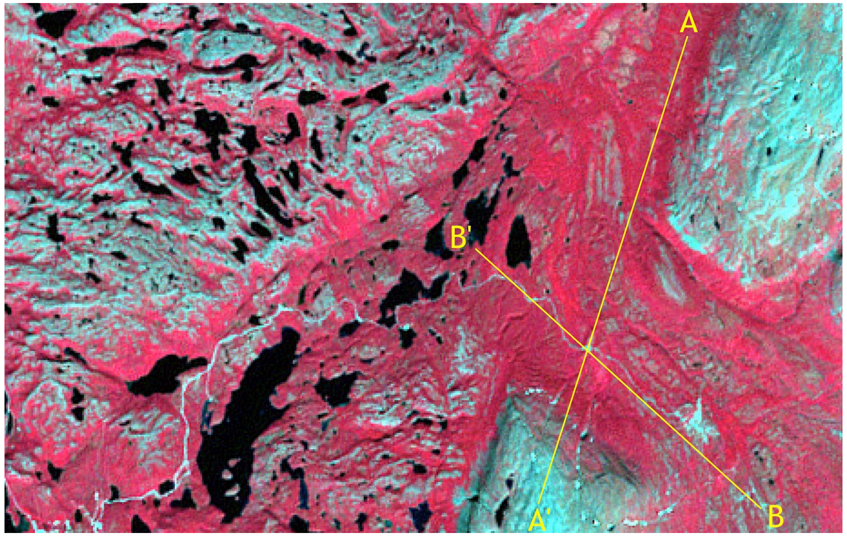


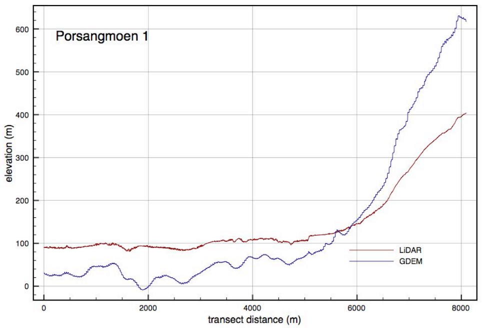


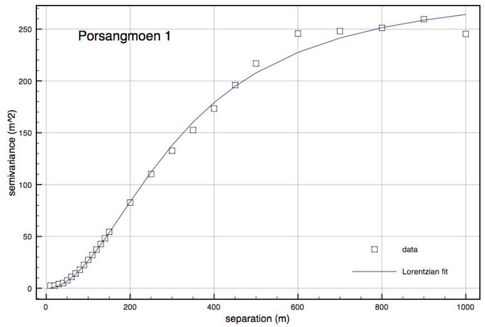
<*n*>	4.7
σ /m	8.7
l / m	91

Reasonable but again blundering on steep terrain

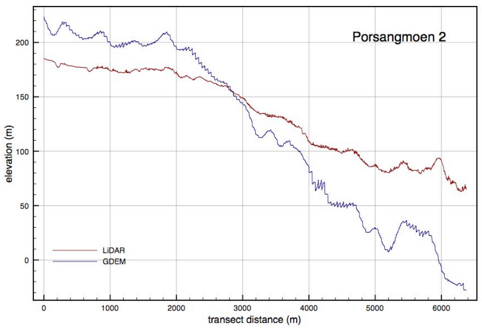
Porsangmoen

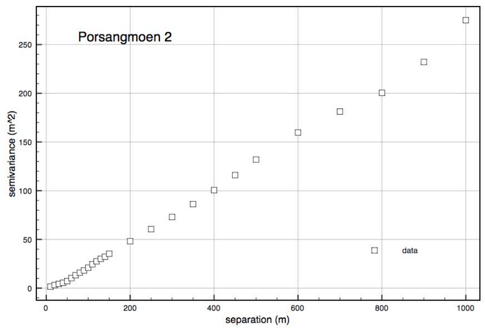






<*n*>	2.2
σ /m	17.0
l / m	315

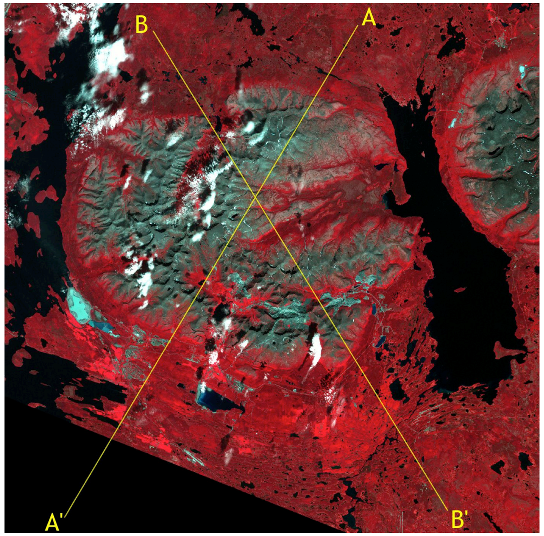


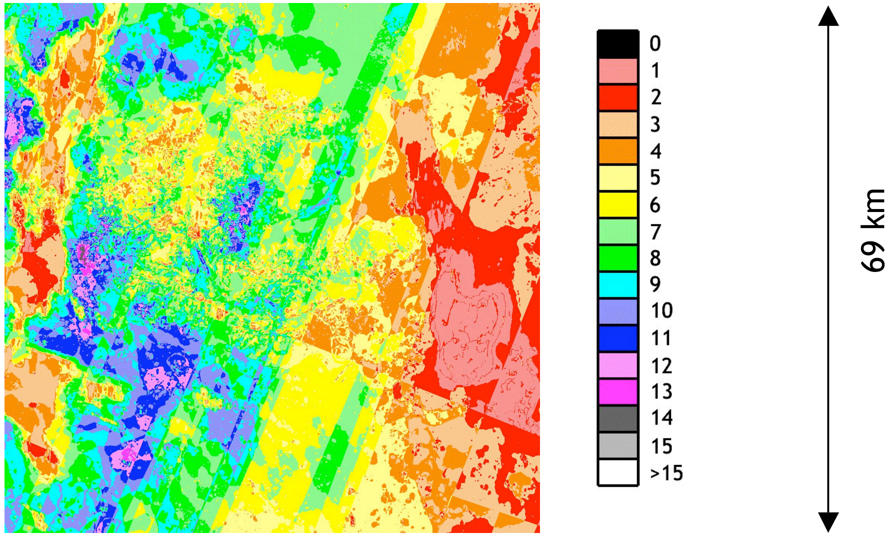


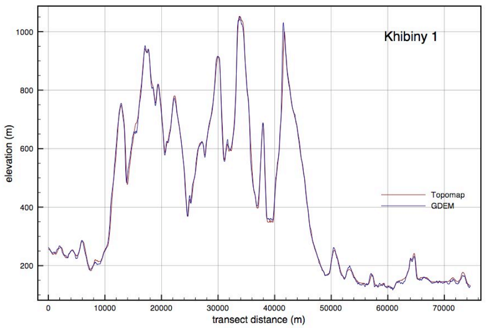
<*n*>	2.6
σ /m	
l / m	

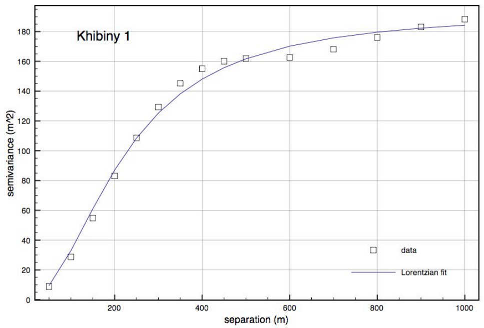
Failure!

Khibiny

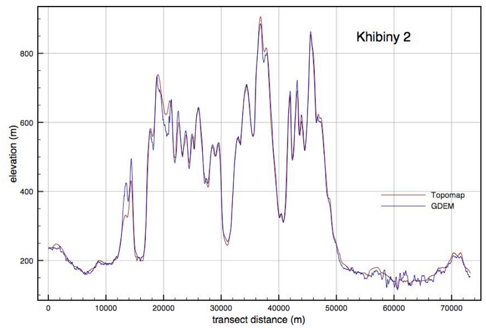


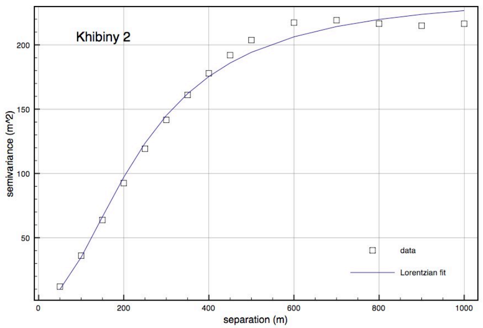






<*n*>	8.7
σ /m	13.9
l / m	221





<*n*>	6.3
σ /m	15.5
l / m	243

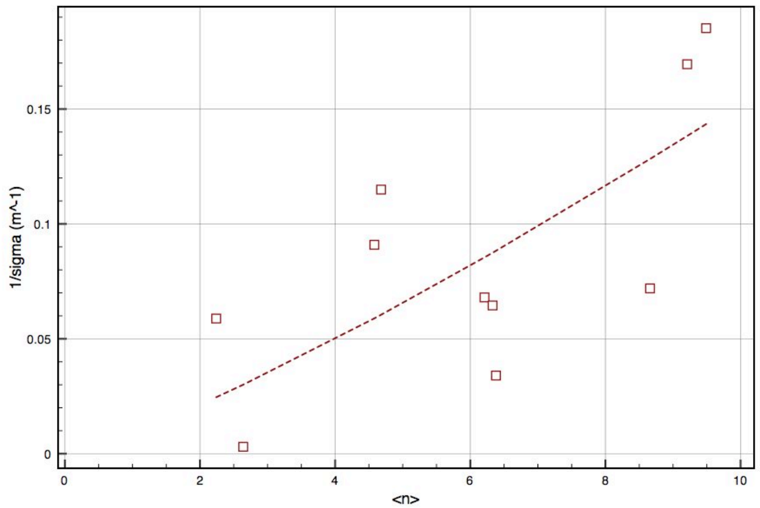
Impressive! Occasional blunders. Significant error contributed by reference DEM

Analysis:

error correlation length ≈ 130 m (*cf* 100-120 m ASTER estimate)

error acf is usually ~ lorentzian

rms error strongly dependent on n, with $n<6$ often unreliable and $n \leq 2$ useless



Typical errors around 5-10 m if $n > 6$.

slope also appears to have some effect on error, though slope and n are correlated. Steeply-sloping terrain is not handled well.

little evidence that ground cover (e.g. reflectance) affects error, although not systematically tested

Observations

Only claimed as experimental product but can be used for research

QA (stack number) data gives a good idea of reliability

Resolves ~ 100 m horizontally

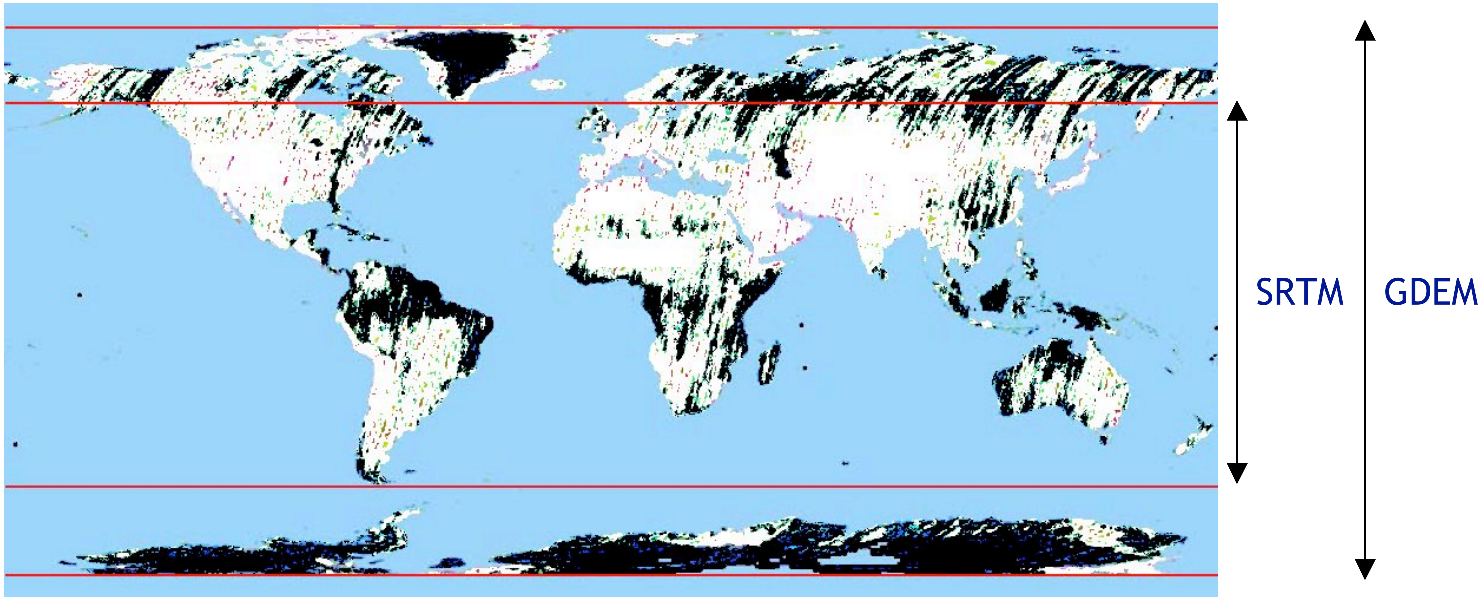
Height accuracy can be as good as 5-10 m

Water bodies are not masked

Responds to dense vegetation surface

Acquisition date is ambiguous ± 5 years

Is GDEM good for polar regions?



- Latitude range from ~60° to 83° is accessible
- GDEM coverage with $n \geq 6$ is
  - poor over Antarctica and Greenland
  - patchy over Asian arctic
  - good in most other parts of polar regions
  - improving over time!

Future developments?

TanDEM-X/TerraSAR-X: InSAR; global, 12 m horizontal, 2 m vertical, 2010-2016.

National LiDAR datasets:

- Switzerland and Denmark completed, 1 m horizontal resolution
- Finland and Sweden in progress

Other national programmes using RS data

- e.g. Canadian programme using Radarsat

Conclusions

- GDEM is claimed only as experimental product but is usable with caution
- Grid interval is ~ 30 m but actual horizontal resolution is ~ 100 m
- Height accuracy can be as good as 5-10 m
- Stacking number appears to be good indicator of likely accuracy
- Geographical coverage of high-resolution DEM has been extended very substantially into the Arctic (relative to SRTM), less so in the Antarctic although this will probably improve
- Future global topography missions are planned